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ELECTRONICS INDUSTRY STUDY REPORT

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ELECTRONICS INDUSTRY STUDY REPORT

ABSTRACT

This paper provides a national strategy for the US electronics industry. Electronics is one of the largest industries in the US and plays a critical role in almost every aspect of national security. It is directly responsible for the economic boom that propelled the US into an unparalleled superpower status. The US has capitalized on advances in computing, semiconductors, storage, optics, telecommunications, intelligent devices and sensors to achieve a competitive advantage. For example, the Semiconductor Industry Association (SIA) reported semiconductors as the number one industry in the US based upon its contribution to the nation's gross domestic product. Semiconductors are fundamental electronic components that form the building blocks of all electronic devices. Consequently, in order to focus the assessment and strategy recommendations, the 2005 ICAF Electronics Industry Study generally used the semiconductor industry as a proxy for the entire electronics industry. Continued growth and innovation of this industry is a critical prerequisite to maintaining our technical superiority and leadership. The electronics industry also has and is expected to continue to have widespread economic and societal impacts.

PLACES VISITED

Domestic

3M, Austin, TX
Advanced Micro Devices (AMD), Austin, TX
Applied Materials, Austin, TX
Electronics Industry Association (EIA), Rosslyn, VA
Dell Computer Corporation, Austin, TX
Freescale, Austin, TX
MIT/Lincoln Labs, Boston, MA
National Science Foundation, Rosslyn, VA
National Security Agency (NSA), Fort Meade, MD
Night Vision–Reconnaissance, Surveillance & Target Acquisition Project Office, US Army Materiel Command, Fort Belvoir, VA
Northrop Grumman Corp, Electronic Sensors & Systems, Baltimore, MD
Raytheon Company, Woburn, MA
SEMATECH, Austin, TX
Virginia Semiconductor Company, Fredericksburg, VA

International

5th Signal Command, US Army, Mannheim and Landstuhl, Germany
La Délégation Générale pour l'Armement (DGA), Paris, France
European Aeronautic Defence and Space Company (EADS), Paris France
Federal Academy of Defence, Mannheim, Germany
IBM, Zurich Research Laboratory, Zurich, Switzerland
Sagem, Paris, France
Siemens VDO Automotive, Babenhausen, Germany
Thales Group, Paris, France
United Monolithic Semiconductors, Ulm, Germany

Table of Contents

Figures

Tables

Appendix

Electronics Industry Study Report

Introduction

The purpose of this assessment is to provide a comprehensive national strategy for the United States (US) electronics industry. It is based on an electronics industry study by students at National Defense University's Industrial College of the Armed Forces (ICAF), class of 2005.

This paper will:
- Define the industry and outline its importance to national security
- Outline trends that are of concern to national security
- Provide a national strategy to address emerging trends.

In order to focus the assessment and strategy recommendations, the 2005 ICAF Electronics Industry Study generally used the semiconductor industry as a proxy for the entire electronics industry.

I. Industry Overview

A. Defining the Electronics Industry

The broadest definition of the electronics industry includes four tiers, roughly aligned with the supply chain (see figure 1). The first tier, on the left in the figure, includes design software and machine tools used to manufacture semiconductors. The second tier includes the basic components of electronic systems, including system software (e.g. real-time operating systems and low level device drivers), semiconductors, and analog and digital discrete devices and power supply components. The third tier consists of major subassemblies that are useful for many applications, such as processor and network components. The final tier, represented by the rightmost column, represents complete electronics tailored for specific applications or markets.

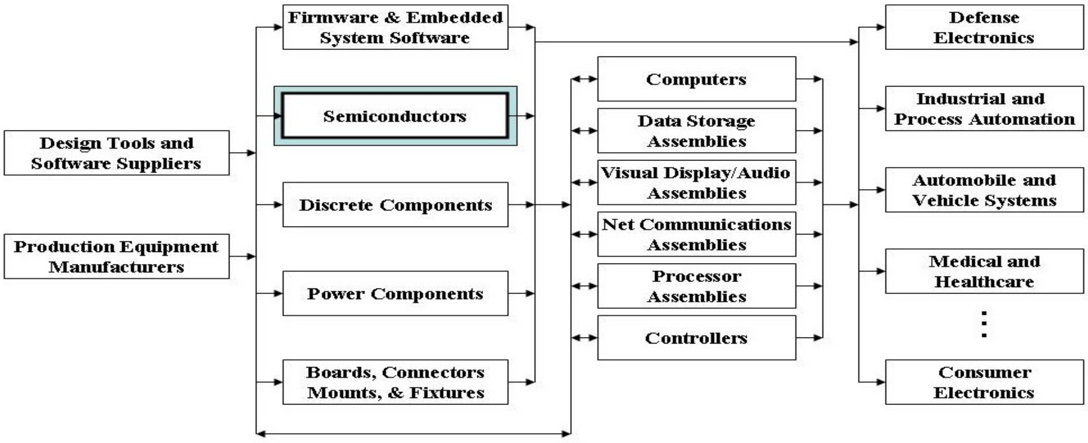

Figure 1 – Supply Chain Driven Electronics Industry Segmentation

The full electronics industry is large and diverse, but the semiconductor industry is the strategic segment. Much of the middle tiers have been commoditized, and the application areas are actually more closely related to their user industries (e.g. automotive and medical systems). The strategic value of semiconductors is based on a number of factors. Enormously expensive production facilities and highly skilled workforce requirements present very high barriers to entry. On the other hand, semiconductors have intrinsic high value and general utility that supports prices over the long term. Finally, electronics provides competitive advantage in almost every other industry yielding a secondary, but substantial, economic advantage at the national level.

During recent decades, the US electronics industry has been one of the key contributors to US competitiveness. Because it is a sector with a "cutting edge" quality, its successes and failures are watched with special attention. Also, many other industrial sectors are increasingly dependent on it, whether it is automobiles, aerospace, advanced manufacturing, medicine, telecommunications, or, of course, defense. The semiconductor industry forms the foundation for all these sectors. During the last twenty-five years, in particular, many Americans have worried about the possible decline of the US electronics industry because of the competition from Japan and, more recently, other Asian countries. Starting with consumer electronics, this foreign challenge grew in certain advanced components and computers. The recession beginning in 2000 witnessed the industry's greatest downturn, one which only now seems to be evoking a resuscitation of electronics and other high tech sectors. Regardless of current conditions, however, discussion continues within government and business circles as to measures that the US Government can take to assist the industry. For this reason, this study will focus on the semiconductor industry as the key electronics industry segment.

B. Defining the Semiconductor Industry

A semiconductor is a material, like silicon, whose properties lie between those of an electrical conductor and insulator. An integrated circuit (IC) is an electronic circuit, with many elements, fabricated and connected on a continuous substrate, like silicon. One of those key elements is a transistor, which is a device that can amplify, switch, or detect a signal. It can also store a bit of information, either a "zero" or "one", represented by the two possible electrical states of a transistor (on or off, charged or with no charge, positive or negative).[1] It is the number of transistors on a semiconductor IC, or chip, that contributes to determining its computing or storage power.

The structure of the current semiconductor industry is based upon the manufacturing process, or value chain, of primarily silicon based ICs. The industry value chain is comprised of four activities, design, wafer fabrication, device packaging & test (P&T), and marketing and sales. Corporate strategies vary by degrees of integration of these three main components of the IC manufacturing process. Semiconductor firms are categorized into one of three basic industry sub-sectors (integrated, fabless, or foundry). Integrated firms are those which carry out the complete set of activities in-house. Firms that design ICs but outsource fabrication to other companies are referred to as "fabless." Firms that exclusively fabricate semiconductors on contract with other firms are called foundries.

To build a state-of-the-art semiconductor fabrication facility, referred to as a "fab," costs about $3-4 billion. Few companies can afford such an investment, which is why the fabless industry as emerged. They pass their designs to foundries that mass produce the ICs. With the assistance of host nation support, proximity to markets and manufacturing expertise, foundries have emerged in several overseas locations, especially in Asia.

The conduct of the semiconductor industry is primarily driven through innovation and rapid changes from one generation of chip technology to the next. This rapid change is characterized by Moore's Law which states the computing power of semiconductors will double every 18 months.[2] Better processes and increased scale have exponentially driven down prices with increases in performance. ICs have gotten faster, better, and cheaper every year. What is the economic consequence of Moore's Law? It is that the advances in technology bring more electronic components with more functionality to a semiconductor device for the same cost. Commensurate improvements in productivity have in turn fueled demand for more ICs, becoming a huge forcing function for economic growth over the past dozen years.

As new technologies develop, like applications from nanotechnology, the industry structure will change. There are other semiconductor substrates, like gallium, that offer enhanced functional performance in several important areas, but silicon based ICs will continue to dominate most industry applications because of the enormous level of existing infrastructure and base of technical expertise worldwide. Accordingly, silicon will not be soon eclipsed when its successor technology hits the market. If it is to be replaced, the primary driver will be economics. In ten years the world will have more than fifty years of research, expertise, and manufacturing equipment invested in silicon technology. The successor to silicon will likely be used for several years in very high end applications until it can be made cost effective enough to replace the average personal computer.

C. Importance of Semiconductors to US Economic Growth and Security

The world recognizes the importance of semiconductors to both the economy and national security. The National Research Council identifies semiconductors as the "premier general purpose technology" of the post-industrial era.[3] General purpose technologies are enabling forces in an economy. They add value by themselves, but more importantly they spur economic growth by creating new opportunities across diverse sectors of the economy. Because they have such broad applications, general purpose technologies drive innovation across the economy and have transformational effects on the way goods are produced, businesses are organized, and wealth created. Historic examples include the steam engine, the internal combustion engine, and electrification. Because of their pervasive effects, they are widely emulated which ultimately leads to rapid growth in demand as the technology diffuses throughout the economy. The primary electronics user industrial sectors are shown in the pie chart.

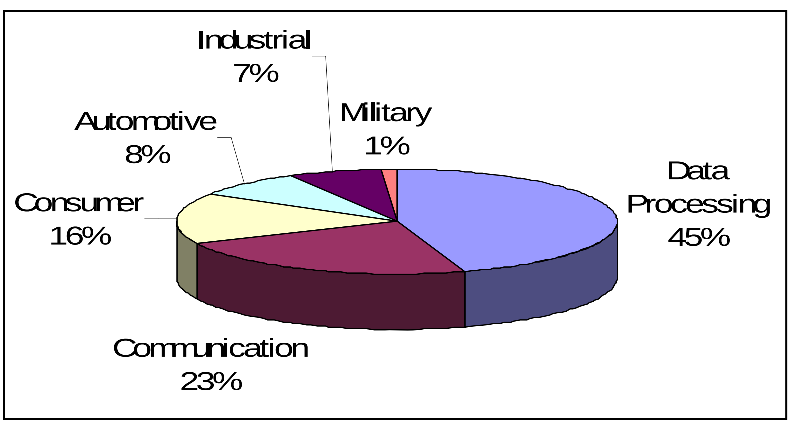

Figure 2 – Primary Electronic User Industrial Sectors

With semiconductors as the foundation, productivity increases have been propelled by the rise of information and communications technologies. Between 1973 and 1995, US productivity grew at a steady but modest 1.4%. From 1995-2000, however, it jumped to a respectable 2.6%. Despite the 2000 recession, productivity continued to grow by almost 1% and as the economy rebounded, productivity growth spiked to more than 4% and has remained at that level for the last several years. This represents the fastest period of productivity growth since World War II.[4]

Since World War II, the US has pursued a strategy of quality over quantity in procuring defense systems. High technology is the force multiplier that has provided our warfighters with the tools to win. America's unrivaled military capability today relies heavily on electronics technology. Microelectronics is a key enabling technology; it makes smart weapons smart, and provides vastly increased capabilities for winning the battles of today and tomorrow against symmetrical and asymmetrical threats.

D. Current Health

By most measures, America dominates the global semiconductor industry. In 2004, the global market for semiconductors was $213 billion.[5] The Semiconductor Industry Association reports that US firms accounted for $100 billion, or 47% of these sales. The semiconductor market is highly competitive globally, generally conforming to the monopolistic competition model, while the more upscale chips are best characterized as highly competitive oligopolies. Three of the ten largest semiconductor companies are US owned and control more than 20% of the world market. Intel, by far the world leader, outpaced its nearest rival, Korea's Samsung, by a factor of 2:1 with more than $30 billion in sales and $7.5 billion profit in 2004, although Intel has been losing market share annually. Texas Instruments was third on the list with almost $11 billion in sales and $1.9 billion profit. Freescale (formerly Motorola semiconductor) rounded out the top ten with $5.65 billion in sales and $211 million in profit. Combined sales for these three companies were almost as much as the total for the seven remaining foreign companies in the top ten.[6] Moreover, eleven additional US companies, while not in the top ten, recorded sales in excess of $1 billion in 2004.[7] The net income of the top 9 US semiconductor corporations from 1998 to 2003 are shown in Table 1.[8]

	Net Income in Millions of Dollars					
Company	2003	2002	2001	2000	1999	1998
Intel Corp	$5,641	$3,117	$1,291	$10,535	$7,314	$6,068
Texas Instruments	$1,198	($344)	($201)	$3,087	$1,406	$407
Maxim Integrated Products	$309	$259	$334	$281	$196	$178
Analog Devices	$298	$105	$356	$607	$197	$120
National Semiconductor Corp	$285	($33)	$122	$246	$626	($1,010)
Linear Technology Corp	$237	$198	$428	$288	$194	$181
Advanced Micro Devices	($275)	($1,303)	($61)	$1,006	($89)	($104)
Freescale Semiconductor Inc	($366)	($1,767)	NA	NA	NA	NA
Micron Technology Inc	($1,273)	($907)	($521)	$1,504	($69)	($234)

Table 1 – US Semiconductor Corporations Net Income in Millions of Dollars

Despite large volumes at the low end of the technology scale, high-end microprocessors still drive the market and US companies maintain the lead in this area. Intel, the undisputed leader in the industry, invests heavily – approximately 14% of revenue – in R&D to remain at the forefront of technology. Similarly, Texas Instruments remains a leader in high-end semiconductors, including application specific integrated circuits (ASICs), standard logic devices and microcontrollers. Freescale, while focusing on the automotive, networking and wireless communications markets, has emerged as the leader in a promising new memory technology, magnetoresistive random access memory (MRAM). MRAM shows potential to one day supplant dynamic random access memory chips (DRAM) and flash memory.

Major foreign firms, conversely, have built their reputations and sales volume on lower end commodities. Korea's Samsung, and Germany's Infineon, for example, are among the world's largest producers of DRAMs. While the DRAM market is an important segment of the overall semiconductor market, it is characterized by high competition, low margins and pending obsolescence as new memory technologies emerge.

While the US continues to drive the technology and be the sales leader, the gaps have narrowed significantly and are unlikely to be maintained based on the current trends. Intel may be the global sales leader, but its revenues are growing more slowly than its major rivals. For example, Samsung's revenue grew 53% from 2003 to 2004 compared to Intel's 11%.[9] Nor are US firms likely to continue their unrivaled dominance in innovation. It was Toshiba, for example, that pioneered flash memory, the technology that has become ubiquitous in disk drives, digital cameras and audio appliances. The industry has become truly global. All trends suggest that foreign companies are approaching parity with their US counterparts. This will have important implications for US businesses and policy makers in the future.

In 1993 total worldwide semiconductor sales were less than $100 billion. In 2004 they exceeded $200 billion and are projected to top $250 billion by 2007.[10] Such growth is even more impressive when it is recognized prices have been continuously falling. This price performance has been a significant factor in minimizing inflationary pressures on the US and global economies.

However, the US share of the global market has declined. In 1982, US companies had a 56% share of global semiconductor sales. Japan was its largest competitor, with a 32% share. It was essentially a binary competition, with market share held by companies outside of the US and Japan a mere 10%. In the last decade, new entrants have altered the landscape. By 2004, the US share (of a significantly larger market) was about 46%. Japan's share had declined precipitously to 26%, while companies in the rest of the world (primarily Asia and Europe) had almost doubled their share to 27%.

Additionally, in 1993 the United States and Japan each consumed a little more than 30% of the semiconductors produced globally. Europe and the rest of Asia split the difference with just under 20% each. During the rest of the decade, Japan's share fell due to its economic problems. Europe and the US share remained relatively level, while the rest of Asia showed a steady rise. Asia is now the most significant geographic market, consuming 40% of the semiconductors produced each year. The US, Europe and Japan split the remaining 60% in roughly equally shares – a dramatic turnaround.[11]

In dollar terms, the growth in Asia is even more striking. Between 1994 and 2004, sales in the US grew from $34 billion to $39 billion, or 15%. In Asia, however, sales grew during the same period from $19 billion to $89 billion, a remarkable 370% increase. Today there are over 300 million mobile phones in China.[12]

Given this shift in global demand, the behavior of semiconductor suppliers has been predictable. New competitors have emerged, especially in Asia, partially due to banking on proximity to growing demand centers to provide competitive advantage. Responding to the new contenders, American semiconductor manufacturers reorganized to be more competitive and better meet demand in emerging markets. Of course, because of their early dominance in the industry, US firms have always had strong international interests. But as the market evolved, these companies became increasingly international. Semiconductor sales to markets outside the US now account for almost three quarters of total sales for US firms.[13]

II: Trends of Concern to National Security

A. Trends in US Electronics Industrial Base

1. Declining Industrial Base; Offshoring of Foundries. If the quest for proximity to the customer recommends overseas manufacturing facilities, the quest for profitability demands it. These twin characteristics have spawned a critical trend – offshoring. In an industry characterized by rapid change, fierce competition, advancing technology, falling prices, and low margins, companies are under intense pressure to reduce costs. As education, skills, and infrastructure improved in emerging markets, US firms discovered they could decrease costs, increase proximity and enhance competitiveness by moving manufacturing operations to lower cost areas made even more attractive by host government subsidies. The global posture of the top three US companies is illustrative. Intel has fabs, assembly and test sites, and manufacturing facilities in China, Costa Rica, Ireland, Israel, Malaysia, and the Philippines.[14] Texas Instruments has over 15,000 employees in production facilities in Japan, India, China, Taiwan, Malaysia, Germany, France, and Israel.[15] Freescale similarly maintains design, research and development, manufacturing or sales operations in more than 30 countries[16].

In 2004, 40% of the semiconductors sold in the United States were purchased from foreign companies, and in 2002 Chinese high tech sales to the US exceeded $33 billion dollars. China surpassed Japan and Mexico that year as the number one foreign supplier of high tech goods.[17] Importantly, 70% of the foundries that support the fabless industry are in Taiwan and 12% in China.[18]

This globalization of the semiconductor industry is a double edged sword for US companies and the US government. Growing sales and new markets create opportunities for expansion and profit, while increased competition drives innovation and ensures low prices for consumers. Offshoring, on the other hand, endangers assured supply to specialized high-tech defense related technologies. In the long run, offshoring also enables foreign companies to replicate successful US business models, manufacturing processes and innovative strategies. If current trends continue, they portend a significant loss of innovative advantage in the industry and, ultimately, the relative degradation of a key segment of the economy that has been an important driver of economic growth.

The movement of significant portions of the semiconductor industry off-shore is a DoD concern because of the loss of: security control, guaranteed long-term access, access to the state-of-the-art technologies, and algorithms built into the circuitry. The growth of off-shore suppliers would be less troublesome if these suppliers were relatively equally dispersed around the globe.

But they are not. The US is becoming overly dependent on Asia for the basic components of our technology.

2. Increasing Involvement by Foreign Governments to Compete. Given the critical impact of this industry on overall productivity and growth, it is not surprising that governments have enacted policies to target information technology industries and tilt the playing field in their favor. The manufacturing migration to Asia was not the result of cheaper labor alone, the primary reasons were host nation support, proximity to demand centers, and availability of human capital. China actively pursued and acquired the business through major incentives and tax breaks. China made investment capital available, eliminated the value-added tax for the first five years of a plant and cut it in half for the second five years, greatly reduced the personal income taxes of electronics workers, and eliminated the capital gains tax. China reduces its 17% nominal value-added tax to 3% for domestically manufactured semiconductors. China also taxes stock options at par value and has no capital gains tax. New fabs in Singapore receive a ten year tax exemption followed by a five year period of reduced tax rates. Taiwan offers foreign companies rent-free leases for two years in designated industrial districts, with reduced rent for the next four years. The impact of these policies is significant. One US semiconductor manufacturer told the President's Council of Advice on Science and Technology (PCAST) that these inducements are worth up to $1.3 billion of a $3-4 billion investment in a new fab.

While inducing foreign companies, governments also provide a leg up to domestic producers. The government of Taiwan provided a full one-half of the $200 million initial investment to start Taiwan Semiconductor Manufacturing Corporation (TSMC) and United Microelectronics Corporation (UMC). Singapore reportedly provided 95% of the start-up costs of Chartered Semiconductor.[19] The German government provided over $780 million (€600 million) in incentives and subsidies to attract a US company (Advanced Micro Devices) to build a fab in Dresden, Germany. Methods used by these governments include, free land, corporate tax rates set effectively to zero, stock option tax rates set at zero, and direct subsidies, grants and reduced-rate loans.

Asia is encouraging capital investment to stimulate infrastructure growth used to produce domestic products from the Asian corporations. Depending on market growth, these may eventually replace the Western corporations now investing there. The reason is simple: for each foreign-owned fab job, many local jobs and infrastructure (roads, sewer, electrical, etc.) for further development are created. It is being used as a national economic development program. Similar to what took place in the Austin, Texas area; one to six local jobs were created for each of the electronics industry jobs. In China, that number is probably doubled.[20] This government assistance is paying off; the Chinese semiconductor industry has a 25% combined annual growth rate. China's alleged desire is for internal manufacturing to meet the internal demand.[21]

B. Trends in US Electronics R&D and Design Effort

"We want to be the fastest growing major industrialized nation in the world tomorrow…and in the future…we can do so if we stay on the leading edge of technology."
– President George W. Bush, June 24, 2004

Just as the IC ushered in the revolutionary, post-vacuum-tube electronic era, similar technological advances are vital to ensure the nation maintains its "dominance". R&D in the basic sciences is the means whereby a radical shift or quantum leap in technology will be initiated to help ensure a continued US technological advantage. However, key trends challenge US continued dominance.

1. Shifting Research, Development and Design Off-shore Activity. Some industry associations, trade groups and political groups focus on the negative aspects of off-shore manufacturing and design efforts. However, these trends have actually had a positive impact on US and global economies. Further, the impressive rise of America's fabless companies would have been impossible without offshore foundries. Interestingly, following in the footsteps of manufacturing, R&D is being shared offshore to benefit from time zone differentials. Design activities can be passed from time zone to time zone across the globe enabling 24-hour work cycles and increasing the speed to market. Previously little-known companies like Quanta Computer, Premier Imaging, Wipro Technologies, and Campal Electronics, are being referred to as "the vanguard of the next step in outsourcing—innovation itself."[22]

The idea that US company executives would only outsource manufacturing, while keeping innovation here at home, is disappearing. Firms such as Dell, Motorola and Philips are now buying designs from offshore firms and subsidiaries, and modifying them slightly for their own niche, and then putting their own labels on them.[23]

Research and development is said to be a "contact sport". This is also the case with respect to the electronic industry R&D base because "more fundamentally, manufacturing is a learning-by-doing industry. Having fabrication facilities in close proximity to R&D facilities is important for researchers and manufacturers alike."[24] "Proximity," however, is becoming redefined as the world becomes more and more connected. It is critical to understand the shift to offshore R&D and to leverage the positive potential of these activities while identifying and maintaining key capabilities on-shore. The loss of US electronic R&D industrial base capability has the potential to limit the production of future technological advances.

This is clearly a very competitive and very globalized industry. Just as semiconductors have become commoditized and manufacturing has moved off-shore, semiconductor design is also rapidly becoming a commodity. TSMC, the world's largest chipmaker, is planning to offer its customers circuitry design and packaging—something that has traditionally been done by US and other foreign firms.[25]

2. Declining Basic R&D Investment. Overall Research and Development investment in the US has maintained a generally constant level 2-3% of GDP for the past several years. However, the predominant allocation of work has shifted from government funded to industry funded R&D. The federal government continues to fund and execute the majority of the nation's basic and early-applied research within the universities and laboratory network. According to the Electronics Industry Association (EIA), "Industry now accounts for approximately 68% of total US R&D expenditures, with three-quarters of that investment going to late-stage development and engineering. Typically, less than 10% of industry R&D expenditures are directed to basic research."[26] Yet, next-generation innovations represent 14% of electronic product launches nationwide, 38% of revenue, and generate 61% of industry profits.[27] Coincidentally, as the industry percentage of total R&D increased, the Federal percentage of basic research decreased proportionally (see figure 3).

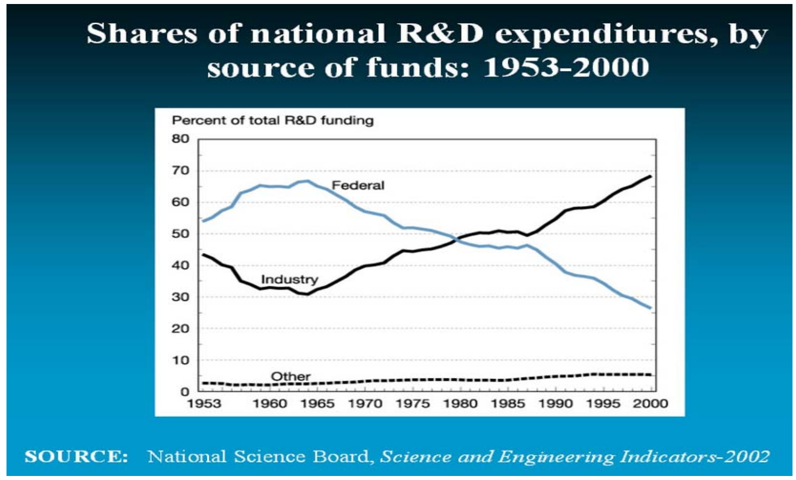

Figure 3 – Shares of National R&D Expenditures by Source of Funds

The implications of the trend for increasingly lower levels of basic R&D within the US hits the electronics industry especially hard. Private industry is concerned with meeting the financial objectives of their company's boards of directors and shareholders. Company executives find it difficult to demonstrate the financial benefit of basic research. The financial risks are high as one never knows when, where, or how basic research will impact the industry. Once the basic R&D knowledge is gained, companies evaluate the findings for potential application within their product areas. One Chief Technology Officer from a major US electronics manufacturer doesn't think that industry can efficiently do the basic R&D; his company spends much less than 1 percent for basic, new technology R&D.[28]

"US federal basic R&D funding that spawned so many technological breakthroughs in the twentieth century is faltering. R&D funding is vital in supporting innovation because it invests in the technologies that will advance society in the future. Unfortunately, *overall electronic industry* R&D funding has *also* declined over the last decade and a half and the priority has shifted to life sciences." Additionally, the Defense Science Board expressed concern that "the focus of the current DOD S&T program is primarily on incremental improvements in current capabilities … and does not place sufficient emphasis on innovative technology initiatives leading to entirely new military capabilities."[29]

While important, these increases of incrementally improved products have come at the expense of basic research. A research director at a major research arm of a leading electronics firm said that "25% of their new patents grew out of their basic research."[30] A healthy, basic R&D culture is necessary to spawn the innovation that fuels economic growth and sustains US technological leadership as confirmed by several industry leaders consulted. This faltering investment in US basic research is a troubling trend.

C. Trends in Science and Engineering Intellectual Capital

"It's not that we're not moving forward; it's that the Asians are moving forward faster than we are."

— US Electronics Industry Executive

The United States risks losing its lead in global innovation because its science and engineering knowledge base is in a decline relative to global rivals. For example, American students are straying from science and engineering (S&E) and choosing careers in the medical, legal, and business fields, most with greater economic returns.

By contrast, and just as worrisome, there has been a major increase in participation by foreign youth, especially Asians, in S&E. This "foreign investment" in S&E education and careers has resulted in a rapidly accelerating accumulation of "intellectual capital" in China, India, Japan, South Korea, and Taiwan.

These two long-term trends threaten the US high tech industry's ability to innovate at the rates necessary for a post-industrial giant like the US to retain its levels of growth, prosperity, influence, and security. For in a global marketplace, as the Council on Competitiveness has noted, national security and competitiveness in high-tech innovation are closely linked.[31] Knowledge facilitates innovation, innovation creates wealth, and wealth funds security. High-tech innovation is directly linked to advanced education and synergistic employment in the physical sciences and engineering. The more knowledge, then, the more secure and prosperous the US will be. The US is no longer the industrial giant it was at the end of World War II. It is post-industrial and a post-industrial nation has primarily one comparative advantage over other nations that forms the basis for trade and the wealth it creates: innovation.

The following trends combine to create the threat:

1. Insufficient Per Capita PhD Production Levels in US to meet future demand. The U.S experienced a tremendous growth in the number of individuals with S&E PhDs as a result of the space race with the Soviet Union. These individuals provided the knowledge base that was required for the space race and its associated technology revolution. The space race inspired a significant number of college students to obtain S&E degrees. However, a block obsolescence problem now exists--1999 National Science Foundation statistics show that a significant number of individuals with S&E PhDs are between the ages of 49 and 57, thus rapidly approaching retirement. Accordingly, although recent numbers of S&E graduates are not out of proportion to historical trends, these levels do not appear to be sufficient for future demands of a high tech, globalized world. This is especially true for defense contractors, who have a particularly hard time due to their need for S&Es with appropriate security clearances.

In 1970 there were 18,052 S&E PhDs awarded (to US citizens and foreigners); in 2003 that number rose to 25,258. While this is an absolute increase, there is really less here than meets the eye. When adjusted for population change, *per capita* intellectual capital has decreased substantially. According to National Science Foundation data, between 1994 and 2003, the number of S&E PhDs awarded to U.S citizens and permanent residents dropped from 18,188 to 15,699. NSF data also reveals a sharp decline from 1994 to 2001 in the number of US citizens and permanent visa holders enrolling in S&E graduate programs. Enrollments declined 25% in math/statistics, 21% in engineering, and 17% in physical sciences.[32] Given forthcoming retirements and increased competition in the globalizing marketplace, we would expect that a post-industrial nation such as the US would significantly increase its per capita PhD levels. Instead, the US experienced a significant *decline* during a time that required a major *increase*.

One electronics industry advocate noted that 40-50 percent of the PhDs in Silicon Valley were Indian.[33] Whereas in the past these non-citizens tended to remain here and become citizens, this is no longer the case because their home countries have economically advanced and now offer attractive "packages" which induce them to return. An additional factor in this loss of talent is recent American policy (e.g. Sarbannes-Oxley) which has reduced the use and allure of stock options. Another electronics industry official captured this problem saying, "It's not that the talent is shrinking; it is shrinking in relative comparison to the rest of the world."[34]

2. Decreasing Interest in S&E Careers among US High School Seniors. When asked what kept him awake at night, a senior official of a large US defense electronics firm said, "It's people; I worry about young men and women being interested in science and engineering."[35] There are good reasons to worry. Declining interest among US 12th graders' is indicated by relatively low test scores, as compared to seniors among our rivals. US students placed 19th of 21 in mathematics and 16th of 21 in science. An ACT policy report noted that the percentage of US high school seniors planning to study engineering decreased from 9% to 6% between 1992 and 2002—a 33% decline in the very decade when competition in the globalized world has become increasingly defined by a nation's ability to compete in the S&E intensive industries.[36]

The industry officials interviewed were almost unanimous that this malaise was their single biggest concern for America. One noted, "Part of it is the poor quality of education at the high school level. We're not turning out the kids and the skills we need. We can't blame China for that."[37]

3. Shortage of Experienced US Scientists and Engineers for DoD work. A senior defense acquisition and R&D leader in the current Bush Administration noted that 9% of the S&E job openings in government and private research labs nationwide remain unfilled because they cannot find enough applicants that meet the security requirements.[38] If the situation today seems difficult, consider ten years from now when the rate of baby boomers leaving the US workforce will increase significantly. More than half of all S&E degreed workers are age 40 or older.[39] This statistic is worse by almost 10 years in DoD where years of post-Cold War "rightsizing" protected the more senior (i.e. older) government service employees. One electronics industry official summed up the problem saying, "We're already having to compete for talent, and we believe the problem is going to get worse in the future."[40]

4. Decreasing Foreign Students and Post Education Stay-Rates. The US is increasingly relying on an international S&E labor force to supply the growing demand caused by retiring baby boomers and declining interest among today's youth. There was a sharp decline between 2003 and 2004 in the number of foreign graduate students in the US. Similarly, the number of visas awarded for high-skilled workers has also dramatically declined. In 1997 the US began to experience a decline in the number of Asian S&Es receiving doctoral degrees in the US. At that same time, the number of Asians receiving doctoral degrees in Asian institutions increased by an even greater amount.[41] In the past, foreign S&E workers wanted to stay in the US and work, but those trends are showing signs of reversal as China, India, and other Asian nations rapidly acquire an increasing share of the sophisticated S&E industry. The best opportunities for the foreign S&E workforce used to be in the US, but that trend is beginning to show signs of reversal.[42] One industry official noted a study which revealed that "80% of all Chinese design engineers did not see themselves in Silicon Valley five years from now."[43]

5. Decreasing Share of World Intellectual Capital. Coincident with this decreased production of US S&Es is the mass production of S&Es in China and other rivals. Not only has there been rapid growth in the number of students receiving technology PhDs from Asian universities, but even with the aforementioned declines, foreign students still comprise 40.8%, 39.2% and 24.0% of total enrollment in US educational fields of engineering, math and computer science, and natural sciences, respectively.[44] Whereas the percentage of 24-year-old Americans with S&E degrees remains between 4 and 6% for the past several decades, our rivals hold from 7 to 9%. And when one compares the sheer numbers of engineering degrees awarded, our rivals win hands down: China, 21% of world's production of S&Es, 219K students; EU, 17%, 180K; Japan, 10%, 105K; Russia 8%, 82K; India, 8%, 82K; US 6%, 59K; South Korea, 5%, 56K; Taiwan, 3%, 26K; Mexico, 2%, 24K; Poland, 2%, 22K. This shows that China, the EU, Japan, Russia and India are all increasing their share of the world's engineering intellectual capital. A final indicator is that the US share of worldwide physics articles published has declined from 29.5% in 1991 to 20.0% only 10 years later in 2001.[45]

As one industry executive warned, "There's a technology learning curve that's required to keep you on the cutting edge; we're concerned about the offshoring."[46] When asked if the U.S was losing intellectual capital to overseas firms, an official from a major semiconductor manufacturer said, "Yes; definitely."[47]

6. Causes of the Relative Decline in US S&E Workforce

a. Advanced degrees not required. US scientists and engineers can work without obtaining a PhD. Foreigners, on the other hand, do not have the prospects that US students have, and their pursuit of a PhD can make a bigger difference back home, or as a foreigner when trying to break into a Western job market that naturally favors domestic students with better language and easier clearance requirements.

b. Lower Relative Salaries for US S&E Degree Holders. Exacerbating the long-lead time in preparation is the relatively modest salaries for post-doctorates in science and engineering when compared with other US careers, such as medical school, law school and business school.[48]

c. Lack of interest among high school students. Besides the lower relative salaries, S&E careers are not as appealing to high school students as they once were. Society more often portrays S&Es as "geeks" or "nerds" rather than heroes or celebrities.

d. Immigration Policy. Several corporation and university top officials have complained that Patriot Act restrictions led to a sharp drop in the number of foreign students studying engineering and computer science here. For US universities, this compounds the pre-existing declining trend of domestic students enrolled in those disciplines. Though the State Department eased those visa restrictions for foreign science and engineering students in February 2005, the long term decline in domestic students is still the problem it was before 9/11 (2001).

Conclusion—the Need for a US Electronics Industry National Strategy

Technology superiority has been since WWII, and will continue to be, a fundamental pillar of the US economic engine and DoD superiority. The trends show that just as electronics manufacturing moved offshore, so innovation is also moving offshore. The US is spending relatively less on basic R&D, and is less interested in education or careers in science and engineering. While there is no immediate crisis, the trends are troublesome. As a Defense Science Board report states, "The rate of this technology migration is alarming because of the strategic significance this technology has on the US economy and the ability of the United States to maintain a technological advantage in the Department of Defense, government, commercial, and industrial sectors…our greatest concern lies in microelectronics supplies for defense, national infrastructure and intelligence applications."[49]

Although this shift is inevitable, it will not be abrupt, nor will it be complete. The US still has critical advantages that offset cost differentials, the most important being that it is the world's largest market for high-tech products. Moreover, the world's best R&D system through universities, government, and industry, a flexible and entrepreneurial business climate, robust infrastructure, respect for intellectual property, and the stable rule of law will continue to anchor leading companies in the US and attract foreign companies.[50]

However, strategic leaders must not assume that we can maintain technological superiority without some real effort on our part—without the same level of effort that we would put into a major defense campaign. We should be proactive and secure America's niche in the globalizing economy as the world's innovators.

Loss of the semiconductor industry would disable a critical cylinder in the engine of US economic growth. While there is no dispute that this industry has been a critical driver of productivity and growth, much of that productivity has derived from application of the technology rather than from its manufacture. Similarly, most economic growth (and the potential for future growth) still comes from the innovative sectors of the industry, not the commoditized sectors. This suggests a significant role for government policy in promoting research and development to continue to drive innovation in the semiconductor industry. Funding and incentives for basic research should be increased and better managed. While supporting the semiconductor industry's progress to the limits of physics, the government should also support efforts to find the next big engine of economic growth.

Our mandate is captured by Vannevar Bush, Director of the Office of Scientific Research and Development during World War II: "For war in the middle future … the ultimate advantage will lie with that nation which has scientific and technical ability widespread among its people, industrial capacity and versatility, and a determined will to prevail. It is here where our strength lies, and it is in these aspects that we must preserve it."[51]

Recommendations— a US Electronics Industry National Strategy

Part I outlined the health of the US microelectronics-semiconductor industry and its importance to national prosperity and security. Part II highlighted the major trends that threaten it. This study proposes a US national strategy to counter those threatening trends. The purpose of this strategy is to begin a broad, dialectic debate that will result in better management of the electronics industry, and better leadership at the strategic level. The strategy has three main components: Operation Industry, Operation Innovate, and Operation Scientia. The concepts behind these components are listed in the Appendix following this report.

A 2004 Rand report states, “Two of the primary national security reasons for the promotion, protection, and/or regulation of specific industries are the need to: Prevent actual or potential enemies from obtaining products, components, or technologies that could be used to harm the United States or its friends and allies; and ensure the security of supply of military-critical products, components, and technologies for the US defense industrial base.”[52] Operation Industry seeks to provide stewardship to the electronics industry to the extent necessary to assure the attainment of US interests for future generations. It aims to avoid too great a dependence on foreign sources which could threaten national security. Operation Industry counters potentially threatening trends and helps secure US interests of having a GDP sufficient to fund steadily increasing social and defense programs. As discussed earlier, foreign governments are actively competing to beat the US in the electronics industry. Therefore, the US government should introduce incentives and support the electronics industry as we do other aspects of the economy. Operation Industry is designed to do just that.

Operation Innovate is a multifaceted approach to fund R&D at the levels necessary for the US to achieve its aforementioned vision—to accelerate the next technology revolution, and to hold the intellectual property rights and intellectual capital for that next technology. Quantum computing and nanotechnology are two key areas worthy of increased basic R&D. Quantum computing may make it possible to decrypt any and all military and financial security systems. Information on the internet will no longer be protected even with the most complex encryption algorithms known to date. If the US is not first to invent quantum computing, then it will be at a major military and economic disadvantage. Nanotechnology may be the key to the continued modernization of ICs beyond the physical limitations of the silicon-based ICs. Nanotechnology offers much promise in increased speeds and functionality above and beyond current IC technology. The first nation to harness the power of nanotechnology will gain both military and economic advantages. Craig Barret, chief executive of Intel, stated, “US leadership in the nanoelectronics era is not guaranteed. It will take a massive, coordinated US research effort involving academia, industry, and state and federal governments to ensure that America continues to be the world leader in information technology.”[53] Thus, both for national security reasons and for the traditional economic argument of positive externalities, basic R&D merits substantial support.

Operation Scientia proposes a multifaceted strategy to counter our relative decline in global intellectual capital and reverse the relative knowledge drain flowing from the US toward our global rivals. Operation Scientia centers on our reassertion that the US will retain its historical comfortable lead or global advantage in the marketplace of innovation. Every corporation positions itself for a niche; a nation can do likewise with a strategic deliberate plan. Operation Scientia is such a deliberate plan. The US must manufacture the new technology innovation breakthroughs. American economic prosperity is derived from discovery of new technologies;

and the wealth of nations will always flow to the country that leads in unlocking the mysteries of creation. The US will never have a monopoly on innovation, but Operation Scientia should assure that the US retains its present relative percentage share of global innovation.

A well-reasoned and managed strategy to incentivize and support the US electronics industry is vital to both our economic and national security. Our high-tech approach to prosperity and security has served us well since WWII, but it will only continue to serve us well if we take good care of the industry, the innovative R&D, and the innovators necessary to maintain our competitive advantage.

Appendix

National Strategy for the US Electronics Industry

The following strategy is designed to help the US remain a leader in innovation. This strategy proposes to maintain America's niche in the global market as innovator of new technologies and their applications in human endeavors. The following strategy complements and is not intended to supplant other strategy recommendations.

1. Operation Industry – An Industry Strategy

a. Project Onshore – This project would demonstrate US federal and state governments' willingness to directly compete with foreign governments luring US microelectronics industry firms offshore with lucrative incentives. A model of this direct competition is Albany Nanotech, the centerpiece of Governor George E. Pataki's $1 billion initiative to bring high-tech companies and jobs to New York. New York built two 300 mm clean room facilities to lure research and development firms to move there, in close proximity to University of Albany. It worked; SEMATECH agreed to lead development of extreme ultraviolet (EUV) technology there.[54]

The point is this: if the "if-you build-it-they-will-come" model used in Asia also worked in Albany, it can work all across the US. *Project Onshore*, then, is about long-term investments that will create and preserve jobs in the US. The State of Texas understands the importance of the semiconductor industry as the driver of the world's economy for the next generation. Texas Governor Rick Perry agreed to $40 million in first-year funding for the Advanced Materials Research Center (AMRC), an effort combining the resources of SEMATECH and the University of Texas System.[55] It is not just the next generation that caused the State of Texas to help fund SEMATECH; the relatively small investment of $170 million in SEMATECH is credited with bringing 40,000 jobs to the Austin, Texas area.[56]

As one industry executive said, "Process technology R&D goes where the fabs go; design follows the market. Thus, the growth is in India and China."[57] Should the US invest in foundries in the CONUS, then startup fabless design companies in the US, like Silicon Labs, Broadcomm, and Altera, could use US foundries instead of Asian ones. One industry official said, "US fabless firms want a foundry in the US…they would be highly supportive."[58]

b. Project Sustainability and Mobility –

1) Expand DMEA. DMEA changed the paradigm to one of saving processes, not parts. Under DMEA's Advanced Reconfigurable Manufacturing for Semiconductors (ARMS), they can transfer industry-developed (commercial) intellectual property and technology to DoD using government held licenses. Its focus is to create partnerships with industry to ensure continued availability of parts for DoD systems and to provide war surge support. It assures a continual DoD supply. This is the first real solution to obsolescence, not just a mitigation strategy like lifetime bulk buys. For example, from the time Lockheed approached DMEA it took only about 4 months to get the first thousand Hellfire missile chips out.

DMEA created a government/industry partnership with “flexible foundry” technology and government-held process licenses. This avoids commercial conflicts, and facilitates semiconductor prototype and low volume runs. DMEA’s industry partnership that secures the semiconductor industries COTS-developed intellectual property (IP) is critical to providing long-term sustainability and rapid mobilization. The DMEA model allows for a “reconfigurable future” where new systems can be designed to use proven and supportable “state-of-the-practice” microelectronic technologies. The DMEA model allows parts to be manufactured on-demand.

2) Expand the Trusted Foundry Program. Due to prohibitively high costs in upgrading the fab at the National Security Agency (NSA), the fab will close in 2006. As a result, NSA initiated a “Trusted Foundry” program to establish a trusted fabrication capability to produce microelectronic components for sensitive Defense and Intelligence Community applications.

The Trusted Foundry program, at a cost of $60-80 million, assures access to state-of-the-art technology. Trusted foundries are being pursued with all the major US semiconductor fabrication companies. Companies must meet the following criteria before being considered for “Trusted” status: security control (classified and unclassified), commercial based technology roadmap, technology stability, access for low volume quantities, quick turnaround and life cycle support. IBM is the first designated “Trusted Foundry” and has a 10-year contract.

With the NSA foundry closing, DoD will go to trusted foundries such as IBM for large runs and DMEA for small runs. NSA wants access to state-of-the-art capabilities for unique applications that only a couple places in the world can create. IBM’s trusted foundry in Vermont provides that capability today.

c. Project Geographical Diversity – This project would work to influence the semiconductor-nanotechnology and high technology industries to diversify in geographic location to areas other than China-Taiwan. It helps India develop the prerequisite infrastructure and helps Central Europe, Brazil and northern Mexico, based on Mexico’s stated desire to create a high-technology corridor.[59] Bangalore, India already looks like Austin Texas, according to one industry official.[60] There are limitations to where we can influence the diversification of industry. One industry executive stated that “Looking at Latin America, there is no infrastructure and no education exists. The loci of manufacturing will probably stay in the US, Europe, Japan and Asia, but the distribution will change.”[61]

d. Project Intellectual Property Rights – This project would secure intellectual property (IP) rights internationally through a treaty and bilateral agreements, with appropriate enforcement requirements, with emerging markets that are disregarding those rights.

1) Reform Patent System. The patent system was created to provide incentives for innovators to add to our national pool of intellectual capital. Instead of promoting innovation, it has become an impediment. Adam Jaffe and Josh Lerner outline the problems and propose solutions in their book “Innovations and their Discontents”.[62] As per their recommendations, we should raise the quality of patents and reduce uncertainty by modernizing the review process. Unless we fix the reverse incentives of the current system, the IP machinery that protects US industry more than any other, could lose its effectiveness and credibility.

2) Secure IP Rights. Collaboration concerning key technology areas can only be exploited with the assurance that IP will be safeguarded. This is especially important in areas that appear to have only limited commercial application. Industry is reluctant to conduct pre-competitive research to help overcome perceived technical risk and financial barriers associated with early-stage technology development and bring technology to market.

f. Project Friendly Environment – This project would seek to retain industry innovation and design leadership by creating an industry-friendly environment. A proper role for the government is to work through existing institutions to ensure fair trade practices. US policy needs to more vigorously address the issues of IP property, government subsidies and extravagant tax incentives. But it needs to do so constructively in order to reinforce the power of the market. Trying to obstruct it by enacting tit-for-tat protectionist measures is counterproductive.

The US must streamline the export license process and clarify which technologies are truly critical to national security so as to increase exports without forfeiting critical military technologies. "Buy America" policies present a disadvantage to US firms. It is not realistic for many subcomponents and preassembled parts. Current export control laws are based on the Cold War and are now an impediment to US national security. Export controls for Defense Electronics firms (France can sell it; but our industry cannot) is a strategic mistake. Dov Zakheim, OSD Comptroller, states, the US "must consider the extent to which its export control policies will assist or hinder the success of its military objectives."[63]

To ensure the US maintains a technological advantage over potential military competitors, the US has long controlled the export of critical military technologies. Under the auspices of the Departments of State (International Traffic and Arms Regulations) and Commerce (Commerce Control List), with advice from the DoD, the US has established a formal process to acquire export licenses for US-produced goods. The need for an export control process to support national security is clear. However, the current process is overly bureaucratic and cautious. It is hurting the defense industry it was designed to protect. Because it can take over six months to get an export license approved, even business that does not threaten the transfer of critical military technology, US companies lose business to more responsive foreign competitors. One industry official stated that "There are some technologies we can't export to China, but our competitors (in France, UK, Japan, and Germany) can.'"[64] That kind of policy doesn't pass the common sense test.

The DSB Task Force on globalization and security of 1999 argued that the US's ability "to effectively deny its competitors access to militarily-useful technology (not just critical military technology) will likely decrease substantially over the long-term…the utility of export controls as a tool for maintaining the United States' global military advantage is diminishing."[65] The DSB Task Force argued that "excessive export controls on technology not only would harm the business prospects of American companies seeking to sell their products abroad, but actually would narrow the gap between American military forces and those of its competitors. The Task Force therefore recommended that the United States focus on protecting military capabilities rather than their constituent technologies."[66] Although some technologies in and of themselves are worth protecting, this new focus on military capability rather than generic technologies is a step in the right direction to update US export control policies.

2. Operation Innovate – An R&D Strategy

Operation Innovate is a multifaceted approach to fund R&D at necessary levels.

a. Project National Technology Strategy – This project would create a national technology strategy to achieve synergy in R&D. The current network of research sites is geographically dispersed, highly competitive, and operates without any centralized management. Several federal agencies and organizations have limited oversight/insight into segments of the system. However, none of these agencies develops and executes an overarching executive strategy to direct the collective technology efforts of the nation. Therefore, we should establish a national electronics and semiconductor technology strategy to ensure all subordinate R&D objectives are aligned with the national strategy.

1) Incentivize US Firms to Keep Core Innovation Onshore. Executives at one research consortium stated, "We feel strongly that retaining R&D is critical; R&D drives productivity enhancement. The US has the innovative edge and we need to retain that."[67] Whereas outsourcing manufacturing, tech support, and administrative work might be financially beneficial to a US firm, the ownership of design is the firm's intrinsic value—it is what separates it from other manufacturers. Lucent, for example, sees that some outsourcing of design makes sense so its engineers can concentrate on the next generation of technologies.[68] The US should find creative ways to incentivize firms to retain core innovation that leads to the next generation of technologies onshore.

2) Enhance Onshore and Allied Collaboration. Some US firms are using ODMs in China-Taiwan for part of their innovation process, buying some parts of the design from them. PalmOne, for example, calls this "collaboration."[69] PalmOne claims to have cut months off development times, reduced defects by 50%, and boosted gross margins by about 20%.[70] But there is no reason why all of this collaboration cannot occur within US and allied nation firms. Creating awareness and incentives should be a priority.

b. Project Government-Industry Partnership – This strategy element would develop government-industry relationships and programs necessary to create the kind of synergy within the US electronics industry R&D that yields competitive advantage. Numerous professional articles, presentations, and recent interviews with leaders from over twenty different government and industry organizations overwhelmingly cite partnering as a crucial element of a successful acquisition and R&D strategy. Scarce R&D resources dictate the need to transform the way the US S&E system operates with industry. The way to achieve "technological dominance" is through "pure knowledge enablement that allows the government-industry team to jointly understand the gaps in technology."[71] No single institution in government or the private sector has the responsibility or motivation to strengthen the US R&D system at the national level. Thus, the federal government along with state and local governments should partner with industry to leverage strengths and mitigate weaknesses to create a "win-win" for the electronics industry as a whole.

An excellent example of government-industry partnering is the Defense Microelectronics Activity (DMEA) collaboration with industry concerning Diminishing Manufacturing Sources (DMS) of semiconductors and integrated chips (IC). DMEA works with industry to "secure

COTS-developed intellectual property with the intent to own the processes, design parts to those processes, and provide a low-volume, long-term supportable technology for the DoD."[72] This solution alleviates the need to re-engineer legacy systems and/or procure lifetime quantities of obsolete parts. DMEA maintains a flexible foundry that can manufacture legacy ICs and microelectronic components thereby supporting older technology for industry and the government.[73]

c. Project Increase Federal and State R&D Investment – This strategy element would call for an immediate increase in US government expenditures on R&D from 1% of GDP to 1.5%, and maintains an R&D lead over major rival countries by at least 0.5% of the US GDP. This strategy element includes the following additional, related objectives:

1) Expand SEMATECH. This strategy element would increase SEMATECH funding from about $170 million today—all from private corporations within the consortium—to $340 million annually with matching funds from the federal and state governments to create additional SEMATECH sites, geographically dispersed to leverage regional expertise and universities. SEMATECH's shared research model was the primary catalyst in reversing the trend of leadership from Japan back to the US; and this strategy element reinvigorates that effort to firmly establish the US as the future innovators of the world's newest world-changing technologies.

SEMATECH currently has an integrated priority list (IPL) of ten key technology gaps for which they need to discover breakthroughs. SEMATECH's new President and CEO, Dr. Michael R. Polcari, was an executive with IBM. He stated that the ongoing work of SEMATECH is so important to the semiconductor industry that he felt it necessary to step forward and take the SEMATECH position. He called SEMATECH "crucial to future progress in the industry."[74] Another industry official stated, "SEMATECH is the world's catalyst for acceleration of the commercialization of leading edge technology."[75] The $170 million annually invested there funds only 340 researchers (230 professionals and 137 technicians).[76]

2) Model Government Labs After SEMATECH. In the SEMATECH model, all research is coordinated and placed on an integrated priority list (IPL). Individual stakeholders pay $10 million as dues and get access to $170 million of research. As one researcher at SEMATECH said, "What one firm learns; all learn, thereby preventing other firms from going down rabbit holes."[77]

3) Improve SBIR Program. Small Business Innovative Research (SBIR) currently invests over $1.3 billion each year in a wide range of technologies through ten government departments and agencies. About 99% of DoD RDT&E goes to five large defense companies, yet 95% of breakthroughs come from small businesses. Experts note that the SBIR program has been highly effective in commercializing numerous technologies, and, thus, the more we increase its funding the more new commercialized technologies we will develop.[78]

4) Increase R&D Investment by Private Industry. This strategy realizes that worldwide competitive pressures made it difficult for private RDT&E to survive, and it, therefore, would provide incentives to industry via tax breaks to increase their research budgets. The first place to start would be to make permanent the currently temporary R&D tax credits.

d. Project Increase Awareness – This project would inform Americans about the risks of offshoring, and the advantages of buying American designed products when the choice is a toss-up. Apple, for example, touts on the back of its iPod “Designed by Apple in California; Assembled in China.” The necessity of success of Operation Innovate cannot be understated. As one industry official described the far-reaching implications, “If we don’t out-innovate them, we’ll go out of business.”[79] Maintaining our technological advantage through continuous innovation is absolutely vital not only to corporations, but also to US national security!

3. Operation Scientia – An Intellectual Capital Strategy

Operation Scientia proposes a multifaceted strategy to counter our relative decline in global intellectual capital to reverse the relative knowledge drain flowing from the US toward our global rivals.

a. Project New Vision – This project would create and champions a new vision: “America the Innovators.” This project casts a vision for America that represents a strategic paradigm shift in answering the question of “what to produce.” The fewer physically demanding jobs we have, the longer our minds will work, thereby paying taxes longer, receiving benefits less. This new vision defines our niche as discoverers and innovators. In today’s and tomorrow’s increasingly globalized, high-tech marketplace, the US will retain and advance its position as holding a virtual monopoly in S&E discovery and innovation, and initial application and commoditization of those new breakthroughs. Some nations will boast the cheapest labor; America will boast the brightest, most adventuring minds.

b. Project Cyberspace Race – This project would create in the national psyche the equivalent of what the space race did in the 1960s to inspire our nation to pursue science and engineering with zeal. It consists of an information campaign to communicate the importance of science and technology as well as the threat of other nations holding different ideologies.

c. Project K-12 Excellence in Math and Science – This strategy element would improve K-12 education, particularly in math and science from our abysmal relative standards mentioned earlier to entrance into the top three in ten years.

1**) Presidential Math and Science Fitness Club.** Students who excel in math and science would be recognized with presidential certificates, similar to the Presidential Physical Fitness Program. Membership in this club has additional age-appropriate privileges for students who qualify. By partnering with the entertainment industry, students would receive special discounts to movies and other services and goods at participating businesses, and certificates from the President for each year they achieve mastery. A similar reading program exists sponsored by Pizza Hut where students earn free pizza for meeting monthly age appropriate reading goals. In addition to the immediate entertainment benefits, these certificates could be used in college applications for additional consideration for acceptance and for financial aid requests.

2**) Presidential Math and Science Scholarship Fund.** Partnering with US undergraduate technical institutions, this fund provides scholarships for students who have achieved extra-ordinary mastery of math and science, regardless of their mastery in other required subject areas. It gives exceptional S&E students the opportunity for college scholarships just as athletes enjoy.

d. Project National Science Foundation (NSF) – This project proposes a paradigm shift within the NSF, creating a separate Recruiting Division with a President-appointed director to excite and recruit America's youth into the sciences and engineering career fields. The National Science Foundation (NSF)—an independent federal agency—has been charged "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…"[80] Given that the US is near the academic bottom of the 21 top nations in mathematics and science test scores, it is clear that the current approach is insufficient.

This project would incentivize students to pursue S&E by luring US students into the high-tech industrial base; it entails a military and corporate-style recruiting effort for Federal service researchers, to include paid graduate program education, geographic location preferences, and retention bonuses at the five-year point for upwardly mobile scientists and engineers.

e. Project Heroes – Researchers at the National Security Agency urged that "we need to teach the population that it's cool to be a geek." Project Hero would create a new culture or counterculture among America's youth that greatly encourages them to aspire to adventurous careers in science and engineering. It publicizes the heroes and role models in math, science, and engineering. It creates written, documentary and historical fiction motion picture biographies for all ages to make these heroes household names that America's youth aspire to emulate.

f. Project Recruit and Retain Foreign Engineers – This strategy element would bring the brightest PhD students to the US and keeps them here as US scientists and engineers. One R&D industry executive said, "If we don't bring their PhD students here, then they will stay there, and we won't have access to their discoveries."[81] Another industry association official, when asked what she would say if the President called her to the White House and asked her counsel on what he should do to help secure American prosperity and security, replied, "Getting more people to fall in love with electrical engineering is going to be extremely important; much of our success has been based on Indian and Chinese engineers working in our industry. And they are leaving in droves to take the middle manager job opportunities in their home countries."[82] We must grow our own electrical engineers and also retain the Indian and Chinese engineers.

This project will also help reduce the Social Security burden, as we allow foreign students into the workforce who are happy to earn US dollars compared to much lower salaries at home, and we are happy to have them innovate for us, pay taxes, but not receive entitlements.

g. Project Continuous S&E Education – This strategic project would put the national will and federal government behind the notion that all Americans should be encouraged to pursue continuous education in high-tech skills and degrees. It creates a partnership with employers and provides a vocational-technology and degreed program tax credit for all continuing education efforts in science and engineering.

h. Project Technology Partnerships – This project would encourage formal partnerships between the high-tech industry, technical academia, and high schools to improve education and increases awareness of the rewards of a high-tech career. It provides apprenticeships for promising high school students during the summer, and provides a link for field trips into industry.

i. Project National Fellows – This project, to be managed by the NSF, would provide the professional recognition and grants, similar to the Nobel prizes, for those US citizen researchers achieving major technological breakthroughs in capability.   Recipients would receive the title of National Fellow and an NSF annual grant of $200 thousand for the next five years.

Endnotes:

[1] Standard & Poor's Industry Survey: Semiconductors. New York. February 24, 2005, pages 33-34.

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